AD 210110

U.S. ARMY ORDNANCE

Technical Memorandum 3-59

INVESTIGATION OF NATURAL MOVEMENTS IN AZIMUTH AND ELEVATION LEVER CONTROL ADJUSTMENTS FOR HORIZONTAL AND VERTICAL POSITIONS

OCO, Research Branch Project No. TB1-1000

human ENGINEERING LABORATORY

ABERDEEN PROVING GROUND, MARYLAND

NOTICES

This information is furnished for information purposes only with the understanding that it will not be released to any other nation without specific approval of the United States of America Department of the Army and that it will not be used for other than military purposes. It is understood that the furnishing of the attached plans, specifications, technical data, and other information to the recipient does not in any way constitute a license to make, use, or sell the subject matter of any inventions which may be embodied or described in the information so furnished, and any manufacture, use or sale which the recipient makes of any such inventions disclosed therein is at the risk of the recipient.

Requests for additional copies of this report will be made to

Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Virginia

Attn: TICSCP-2

This report has been released to the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., for release to the general public

OCO, RESEARCH BRANCH
Project No. TBI-1000

Report Number:
Technical Memorandum 3-59

INVESTIGATION OF NATURAL MOVEMENTS IN AZIMUTH AND ELEVATION LEVER CONTROL ADJUSTMENTS FOR HORIZONTAL AND VERTICAL POSITIONS

By

Richard G. Lazar - James R. Williams

April 1959

APPROVED: John D. Weisz
JOHN D. WEISZ
Director
Human Engineering Laboratory

U. S. ARMY ORDNANCE HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

ABSTRACT

This study was designed to:

1. Determine population stereotypes or "natural" movements involved in the operation of levers designed to control Elevation and Azimuth movements.

2. Determine in which plane levers should be placed to better effect control; i.e., the HORIZONTAL or the VERTICAL plane.

One hundred twenty-eight United States Army enlisted personnel were tested on two types of control panels, one VERTICAL and one HORIZONTAL with an Azimuth and Elevation control on each control panel.

The results indicated that there is a consistent relationship between RIGHT and LEFT control movements and RIGHT and LEFT movements of a display in both the HORIZONTAL and VERTICAL positions. However, the major finding was that there is no such consistency or "natural" movement or population stereotype with vertically positioned lever controls which move FORWARD and BACKWARD when these controls are associated with an UP and DOWN display movement. This result has not been reported in past research.

The HORIZONTAL control position was found to be more conducive to better performance although the VERTICAL control position was preferred by most subjects.

The results emphasize findings previously reported in the literature that lever controls should move in a direction consistent with display movements.

CONTENTS

INVESTIGATION OF NATURAL MOVEMENTS IN AZIMUTH AND ELEVATION LEVER CONTROL ADJUSTMENTS FOR HORIZONTAL AND VERTICAL POSITIONS

INTRODUCTION

The problem of control design has been recognized since World War II. During and after World War II, research in the area of control design was especially stimulated by requests for data from engineers and designers of military equipment. They were concerned with accuracy and speed of control operations as a function of size, shape and location of controls. Most of the early work was exploratory in nature. Later work, however, developed into a more refined, controlled search by psychologists and engineers for relevant data and specific control problems.

Selection of the proper control to satisfy the requirements of a particular job is of great importance to the military equipment designer. It is the desire of the human engineer to determine the specific control-display arrangements which are most efficient in terms of reducing time and error factors. The major concern is how to devise a control display configuration which is most "natural" for the operator.

"Natural" responses are those parts of human performance which are generally considered to be either inherent or simply stereotypic of a particular population. It has also been stated that "natural" responses are responses which people have been trained to make either through formal training or through other exposure within their environment. The ease of learning and maintaining a particular response movement depends upon the nature of the control-display relationship. It has often been found that there are "expected" or natural specific control movements which should result in specific display movements. The one basic principle that can be derived from the literature (2,6,9,10,11,20,21,22,23,28) is that control and display should move in the same direction and should be in the same plane. Operator efficiency and ease of learning would thus be an optimum in terms of reducing error and varying time factors.

It has often been stated (2,5,9,25,26) that stress situations may result in a reversion to a "natural" response pattern which may be opposite to a response pattern that is established as a result of training. The main problem in dealing with stress is the difficulty of obtaining real stress under simulated conditions.

Vince (26) attempted to create a stress or disturbing situation in the laboratory by introducing distracting stimuli while subjects were performing discrete up and down movements of a handle. One group of subjects was trained in the "expected" or natural directional relationship between display signals and control movements and the other group was trained in the "unexpected." One conclusion made was that stress conditions will upset the "unexpected" response more than the "expected" even when subjects are given equal training to the same criterion of accuracy.

Andreas, Green and Spragg (1) state that we should use "natural display-control relationships wherever possible in the design of equipment instead of the "unnatural" since the "natural" relationship is more resistant to interference effects than the "unnatural." Carter and Murray (5) point out that "if the display and response required are very simple and if considerable time is allowed for responding, the display-control relationships may not be important, but if the display or response required is complex or if the operator is hurried, the display-control relationships are of extreme importance." In a combat situation an operator may be considered to be "hurried." In the absence of any possible inherent naturalness, specific training can result in the learning of particular responses which become natural. Training methods should be intimately linked to scientifically predetermined natural or "expected" patterns so as to form a strong response habit which will be resistant to breakdown under stressful situations.

It seems apparent that even for general situations independent of stress, that it is highly desirable for equipment designers and human engineers to determine the more "natural" or the "expected" or the population stereotype manipulation of a control. Chapanis (6) states that, "Psychologically, certain directions of movements are natural. At least they go along with other things we are doing. To avoid errors, the control should be designed to take account of such natural bents on the part of operators."

Humphries (11) conducted a study closely related to the interest of this investigation. His data indicates that the horizontal position of controls for elevation and azimuth adjustments is better in terms of tracking performance than the vertical position. His results also indicate that where the direction of movement of the control is consistent with the movement of the display, performance will be optimized.

Past research has mostly been concerned with knobs, cranks, dials, and levers on tracking tasks or matching tasks with apparatus such as the Toronto Complex Coordinator (11,12,24), the modified Mashburn Apparatus (13,14), the Turret Pursuit Apparatus (13,15,16) and the modified Two-Hand coordinator (13,17,18,23). The display used in this study was different than any used previously. The display was a missile model.(See Figure 1) The purpose of using the display was to determine the type of natural movements which exist in regard to missile control operations through a greater degree of simulation than has been achieved in past research.

In general there has been a great deal of work done on control design. The need now exists to determine particular solutions for particular problems. In line with this goal, this study was conducted:

1. To determine the "natural" movement in the operation of Azimuth (AZ) and Elevation (EL) controls.

2. To determine the optimum control position HORIZONTAL or VERTICAL.

For purposes of this experiment, "natural" movement will be specifically defined as the instantaneous response to a verbal command stimulus of UP, DOWN, RIGHT or LEFT.

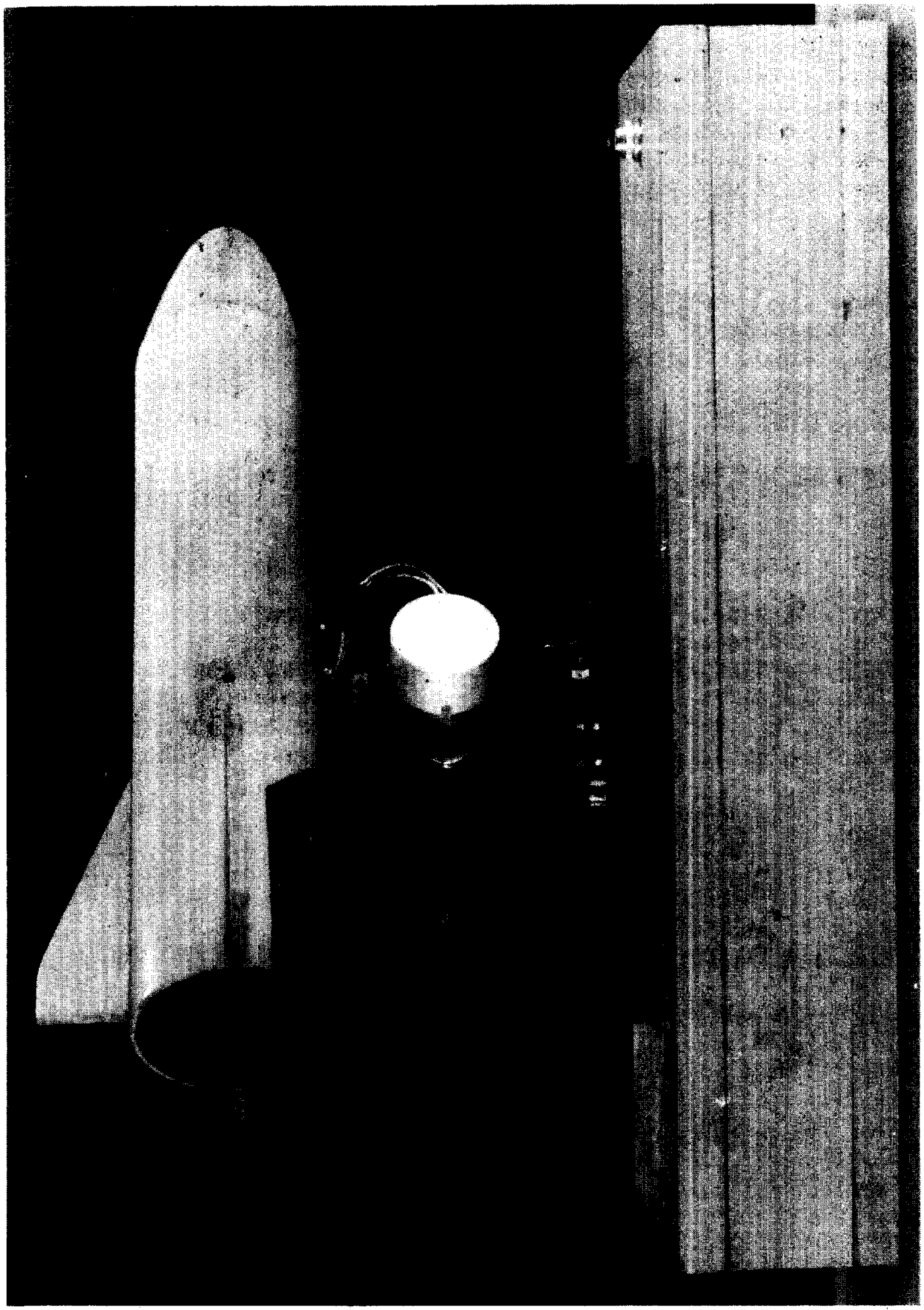

Fig. 1. Missile Model

METHOD

Apparatus

The apparatus consisted of a missile model, 2 control panels, each 8" X 15" with 3" long lever controls, a stop clock calibrated in hundredths of a second to measure reaction time, a relay, and a table, 5' long, 16" wide, and 43" high. The missile model was supported by a pivot post atop a 2-1/2 inch platform. (See Figure 1). The missile was moved RIGHT, LEFT, UP or DOWN with an AZ control and an EL control. There were 2 black control panels, each having an AZ control and an EL control. Alongside each control lever was an arrow indicating the 2 way direction of movement of the lever.

Subjects

The subjects (Ss) were 128 U. S. Army enlisted personnel. They were students and instructors at the Ordnance School Automotive Branch, at Aberdeen Proving Ground, Maryland.

Procedure

The S stood at the table directly in line with the control panel and the missile. The missile was at the far end of the table with its longitudinal axis perpendicular to the frontal plane of the S's body. (See Figure 2).

The two control panels were used alternately according to a random ordered block of 32 presentations. The lever controls were either presented in a HORIZONTAL or a VERTICAL position. One control panel had the AZ control on the right and the EL control on the left. The other had the AZ control on the left and the EL control on the right. The missile model was pointed forward on its platform and the control panel was appropriately placed prior to each presentation.

Instructions to the Ss were as follows:

"THIS IS A STUDY TO FIND OUT CERTAIN INFORMATION ABOUT NATURAL MOVEMENTS RELATED TO THE USE OF LEVERS ON GUIDED MISSILES. YOUR HELP IN THIS STUDY WILL ENABLE US TO DESIGN BETTER EQUIPMENT FOR MISSILE SYSTEMS.

"I WILL GIVE YOU CERTAIN INSTRUCTIONS WHICH YOU SHOULD RESPOND TO AS QUICKLY AS POSSIBLE. THIS IS A MODEL OF A MISSILE - NO PARTICULAR MISSILE - JUST A GENERAL IDEA OF A MISSILE. THIS IS THE CONTROL PANEL WHICH WILL BE USED TO POSITION THE MISSILE PRIOR TO LAUNCHING. ONE LEVER IS USED TO MOVE THE MISSILE UP AND DOWN AND THE OTHER IS USED TO MOVE THE MISSILE RIGHT AND LEFT. THE ARROWS ON THE PANEL ONLY INDICATE THE DIRECTION THE LEVER MOVES.

"PUT YOUR PREFERRED HAND ON THE TABLE DIRECTLY BETWEEN THE TWO LEVERS ON THE CONTROL PANEL. LEAVE YOUR OTHER HAND AT YOUR SIDE. I AM GOING TO TELL YOU TO POINT THE MISSILE EITHER RIGHT, LEFT, UP OR DOWN. NOW REMEMBER TO RESPOND AS QUICKLY AS POSSIBLE TO THE COMMAND BY MOVING THE APPROPRIATE LEVER.

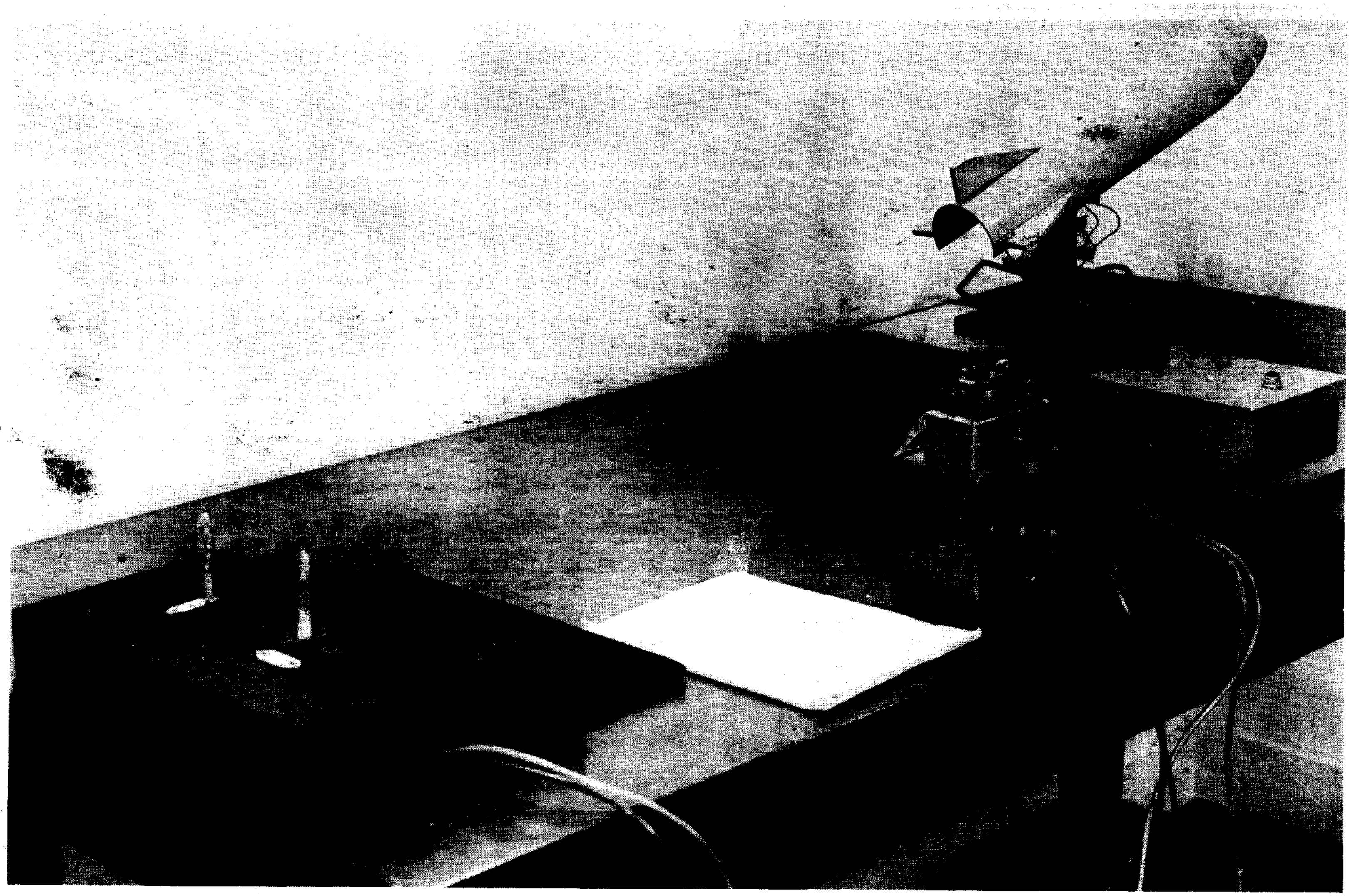

Fig. 2. Missile Model, Stop Clock and Control Panel with Controls in the VERTICAL position

"ARE YOU READY TO PROCEED?

"POINT THE MISSILE ...."

Each S received one trial with the AZ control and one with the EL control. Both trials were presented with the control panel in either the VERTICAL (Figure 3) or the HORIZONTAL (Figure 4) position.

In response to an AZ command (RIGHT or LEFT) the Ss had a right or left choice of control movement available to them which was the same in both the HORIZONTAL and VERTICAL planes. However, with the EL variable, the choices were different in the HORIZONTAL and the VERTICAL planes. In the HORIZONTAL position, the S had either an UP or a DOWN choice of control movement, whereas in the VERTICAL plane, the S had a FORWARD or a BACKWARD choice in response to an EL command.

The S was instructed to point the missile UP or DOWN and RIGHT or LEFT. Only first responses were analyzed. Second responses were obtained to give the Ss a familiarity with both AZ and EL controls in order to enable them to more reliably establish a preference for either the HORIZONTAL or VERTICAL control position.

Responses were recorded for the direction of movement of the control and for the speed of response (latency). The latencies were taken in hundredths of a second as measured on the stop-clock.

A counterbalanced order and randomized presentation of trials was employed. Half of the Ss comprised the VERTICAL group. The other half comprised the HORIZONTAL group. Within each of these groups half the Ss received an EL command first and the other half received an AZ command first.

The following is an illustration of the experimental design:

CONTROL TYPE	CONTROL POSITION: Vertical	CONTROL POSITION: Horizontal	
Azimuth	32 Ss	32 Ss	64
Elevation	32 Ss	32 Ss	64
	64	64	128

An illustrative presentation for two Ss is as follows:

S	Trial 1	Trial 2	Control position
S1	AZ (RIGHT)	EL (DOWN)	VERTICAL
S2	EL (UP)	AZ (UP)	HORIZONTAL

Fig. 3. Subject in the "Ready" position with the Control Panel in the VERTICAL position

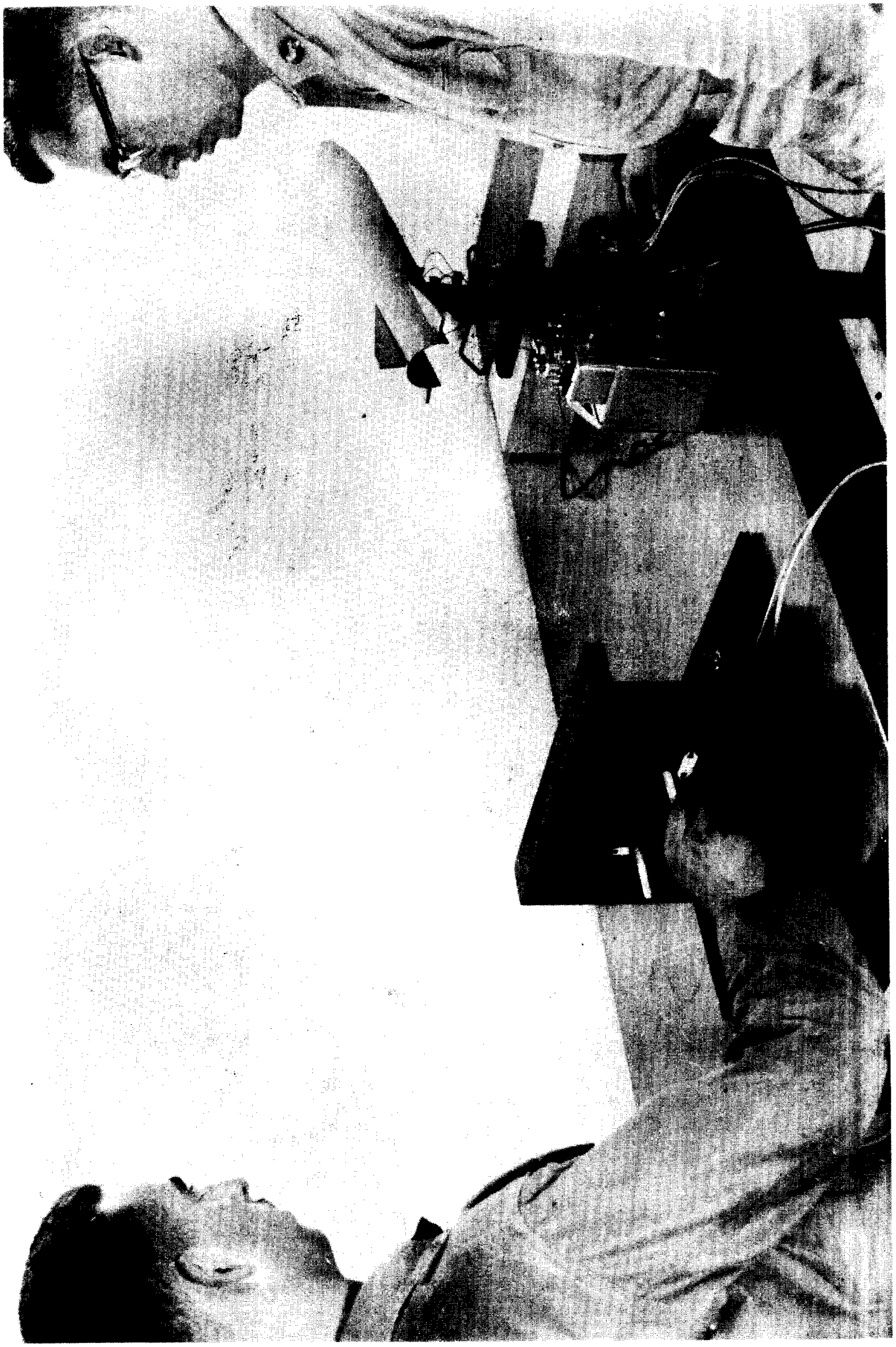

Fig. 4. Subject in the Experiment with the Control Panel in the HORIZONTAL position

In the second part of the experiment, Ss who had been presented with the control panel in the VERTICAL position were then presented with the control panel in the HORIZONTAL position. The Ss who were first presented with the HORIZONTAL position were then presented with the control panel in the VERTICAL position. An S would be given the same two command stimuli he had received in the first part of the study. Responses in this segment were recorded but were not analyzed. The purpose of this part of the study was to allow the S an opportunity to try both the HORIZONTAL and VERTICAL control positions. His preference was reported to the experimenter.

RESULTS

Both frequency and latency data were obtained. Only first response measures were analyzed for reasons previously explained. With regard to the frequency data, the VERTICAL position was compared with the HORIZONTAL only on the AZ variable. The comparison of the HORIZONTAL and VERTICAL positions was not made on the EL variable since it was not possible to make comparisons of equal factors. A RIGHT movement is comparable and equivalent to a RIGHT movement in both the HORIZONTAL and VERTICAL planes and a LEFT movement is also comparable and equivalent to a LEFT movement in both planes. However, for purposes of satistical analysis, an UP movement in the HORIZONTAL position is not directly comparable to either a FORWARD or a BACKWARD movement in the VERTICAL position. Similarly a DOWN movement was not comparable to either the FORWARD or BACKWARD movement in the VERTICAL plane.

It is sometimes assumed intuitively that a BACKWARD movement of a lever control is related to an UP movement of a display and a FORWARD movement of the control is related to a DOWN movement of a display. Since the purpose of this investigation was to determine just what the natural movement is, such an assumption could not be made.

Fisher's Exact Probability technique was used to analyze the frequency data of the EL variable. It was found that there was no significant difference between the HORIZONTAL and VERTICAL positions when the command stimulus "Point the missile RIGHT" was presented. (See Table 1).

TABLE 1. FISHER's EXACT PROBABILITY (P VALUES) of DIFFERENCES BETWEEN HORIZONTAL AND VERTICAL CONTROL POSITIONS ON THE AZIMUTH VARIABLE FOR RIGHT AND LEFT COMMAND STIMULI.

P VALUE	COMMAND
.2419	RIGHT
.7000	LEFT

Of 16 Ss in the HORIZONTAL group given the command stimulus RIGHT, 14 moved the control RIGHT and 2 moved the control LEFT. (See Table 2)

TABLE 2. FREQUENCY DATA OF DIRECTION OF MOVEMENT RESPONSES FOR VERTICAL AND HORIZONTAL CONTROL POSITION ON THE ELEVATION VARIABLE

STIMULUS COMMAND

MOVEMENT RESPONSES	LEFT VERTICAL	LEFT HORIZONTAL	
RIGHT	2	2	4
LEFT	14	14	28
	16	16	32

STIMULUS COMMAND

MOVEMENT RESPONSES	RIGHT VERTICAL	RIGHT HORIZONTAL	
RIGHT	16	14	30
LEFT	0	2	2
	16	16	32

In the VERTICAL group all 16 Ss moved RIGHT in response to the RIGHT command. There was also no significant difference between the HORIZONTAL and VERTICAL positions when the command stimulus LEFT was presented. Of 16 Ss in the HORIZONTAL group, 14 moved LEFT and 2 moved RIGHT. Of 16 Ss in the VERTICAL group, 14 moved LEFT and 2 moved RIGHT. These results indicate that in both the HORIZONTAL and VERTICAL control positions, the natural response consistent with a display movement to the RIGHT is a control movement to the RIGHT and the natural response consistent with a display movement to the LEFT is a control movement to the LEFT.

Some apparently unusual results were obtained concerning the EL variable. In response to an UP command in the HORIZONTAL plane, 14 Ss moved the control UP and 2 Ss moved DOWN. In the VERTICAL plane, 14 Ss moved BACKWARD in response to the UP stimulus command and 2 Ss moved FORWARD. In response to a DOWN stimulus in the HORIZONTAL plane, 13 Ss moved the control lever DOWN and 3 moved it UP. However, in the VERTICAL position, 11 Ss moved the control BACKWARD in response to the DOWN stimulus and 5 Ss moved it FORWARD.

Prior to performing analyses of variance of the latency data, a Bartlett's test for homogeneity of variance (7) was performed on both the AZ and EL variables. The tests revealed heterogeneous variances. Inspection of the data on the EL variable pointed out that two scores out of the total n of sixty-four were so extreme as to distort the mean values and consequently the variances. The individual differences of these two scores, Subject 14 in the HORIZONTAL-DOWN group and Subject 10 in the VERTICAL-DOWN group were responsible for the heterogeneity of within-group variances. These two scores were eliminated from the data as were the two most extreme scores in each of the other two groups. They were the scores for Subject 14 in the HORIZONTAL-UP

group and Subject 5 in the VERTICAL-UP group. Another Bartlett's test was then performed with the four extreme scores removed and the result was that the variances were now homogeneous. A 2x2 factorial analysis of variance (7) of the EL variable revealed that there was no significant difference between the control positions. (See Table 3)

TABLE 3. SUMMARY OF 2x2 FACTORIAL ANALYSIS OF VARIANCE OF RESPONSE LATENCIES COMPARING CONTROL POSITIONS ON THE ELEVATION VARIABLE

SOURCE OF VARIATION	SS	d.f.	MEAN SQUARE	F	P
Between Control Positions (HORIZONTAL-VERTICAL)	.03	1	.03	.08	7.05
Between Direction of Movement (UP-DOWN)	.19	1	.19	.50	7.05
HORIZONTAL-VERTICAL x UP-DOWN	.21	1	.21	.55	7.05
WITHIN	75.87	60	1.26		
TOTAL	78.24	63			

The .05 level of confidence was used as the level of significance.

The Bartlett's test of the AZ variable revealed heterogeneity of variance even with the extreme scores removed. (See Table 4)

TABLE 4. SUMMARY OF BARTLETT'S TEST FOR HOMOGENEITY OF VARIANCE ON EL AND AZ VARIABLES WITH THE EXTREME HIGH SCORE IN EACH GROUP REMOVED

	X^2	X^2 Corrected	P
AZ	14.16	13.13	.01
EL	5.91		.05

Transformation of the data was deemed unwarranted and fruitless. It was invalid to perform an analysis of variance due to the heterogeneity of variance. It was felt that no true difference exists between the HORIZONTAL and VERTICAL control positions due to the fact that the major portion of the variation could be ascribed to individual differences which are the main component of the within-group or error term of the analysis of variance.

Qualitative data obtained through direct inquiry at the end of the experiment revealed that 61% or 79 Ss out of the 128 preferred the VERTICAL control position, while 47 or 38% preferred the HORIZONTAL position.

DISCUSSION

Analysis of the data generally indicated that there were no essential differences between the HORIZONTAL and VERTICAL positions on both the EL and AZ variables in terms of either frequency or speed of response. However, examination of the data reveals some important information pertinent to control design.

In agreement with previous research (2,6,9,10,11,20,21,22,23,28) it was found with reference to the AZ variable that the direction of control movement was consistent with the display movement (a RIGHT response to a RIGHT command and a LEFT response to a LEFT command). Apparently this is the natural response pattern or population stereotype.

It was also noted that in the HORIZONTAL position for the EL variable, the direction of movement of the control was consistent with the direction of movement of the display. An UP command resulted in an UP control movement and a DOWN command resulted in a DOWN control movement. No population stereotype was found for the EL variable in the VERTICAL position. The data indicates that the response for an UP command is a BACKWARD movement. However, a BACKWARD movement was <u>also</u> the response for a DOWN command. Thus, the BACKWARD movement was found <u>to be</u> the response to both an UP and a DOWN command stimulus in the VERTICAL position.

In light of the lack of emergence of a population stereotype response pattern for the VERTICAL position on the EL variable, it might be considered surprising to find that the Ss preferred the VERTICAL control position as opposed to the HORIZONTAL control position. Humphries (11) found that performance was better in the HORIZONTAL position as compared with performance in the VERTICAL position. It appears evident that there is a difference between what an operator considers best and what his performance indicates in terms of control positioning.

Based on the data, it can be concluded that the HORIZONTAL position is best for EL adjustments if the movement of the control is in the same direction as that of the resulting display movement.

The HORIZONTAL and VERTICAL positions for lever controls are equally adequate for AZ adjustments as long as the axes and movements of the control and the display are in the same direction.

It is recommended that EL control levers be designed to be placed in the HORIZONTAL position for missile adjustments. Secondly, in the event that one control lever is used for both AZ and EL adjustments, it would be best if this control were placed in the HORIZONTAL position.

Intuitive guesses as to what particular control-display arrangement is best, are not sufficient. This has been pointed out in this study. There are those who believe that there is a clear-cut relationship between a display movement UP or DOWN and a control movement FORWARD or BACKWARD. Those people assume that the aircraft joystick system of pulling BACKWARD will result in a display movement UP and moving FORWARD will result in a display movement DOWN. However, in an aircraft the pilot also

moves and becomes integrated with the entire dynamics of the situation. In orienting a missile prior to launch the operator usually does not move. In work utilizing the Toronto Complex Coordinator (11,12,24), the "expected" or "standard" control-display arrangement required the operator to move the control stick FORWARD, or away from himself, to make a green light move up the display, and BACKWARD, or toward himself, to make the green light move down the display. Bilodeau (3) used a forward pointing control lever and reported that when the topmost series of lights on a vertical panel was lit, 72 per cent of the Ss expected a DOWN movement of the light when the lever was pulled. Brown, Wieben and Norris (4) reported that reaction time for primary movements is slower on lever operations that require TOWARD and AWAY from movements than on RIGHT and LEFT movements.

It was stated by McFarland (19), in dealing with direction of movement controls, that "When discrete responses are required, fewer errors occur when the movement of a control lever produces a movement in the 'expected' direction; i.e., when an upward movement of the control produces an upward movement of the display. On other display-control relationships, a forward movement of the control to move the display UP with a backward movement to move the display DOWN, was found to be the second best relationship." Vince and Mitchell (27) report this same conclusion.

Research has clearly shown that some control-display relationships will lead to different "expectations" for different operators and even for one operator on successive occasions. In conclusion, it is therefore imperative, especially from a military viewpoint, to search for the "natural" response of a specific control design problem. The determination of a "natural" response tendency will therefore facilitate training. The end product of this type of approach for tactical purposes will be a more efficient man-machine system.

SUMMARY

The present study was undertaken:

1. To determine the "natural" movement in the operation of Azimuth (AZ) and elevation (EL) controls.

2. To determine the better control position, HORIZONTAL or VERTICAL.

Natural movement was operationally defined as an instantaneous or initial response to a directional command stimulus, RIGHT, LEFT, UP or DOWN. An objective of the study was to determine the natural movements on missile control operations through a greater degree of display simulation than there has been heretofore.

One hundred twenty-eight U. S. Army personnel were used as subjects (Ss). Each S received an AZ and EL stimulus command. Their task was to move the control lever appropriately in order to move the missile model in AZ or EL. Frequency and latency data were obtained. Half the Ss comprised the VERTICAL group and half the HORIZONTAL group. Within each of these groups, half the Ss received an EL command first and the other

half received an AZ command first. Only first responses were analyzed. In the second part of the experiment the Ss who were presented with the control panel in the HORIZONTAL position were then presented the VERTICAL position. Those who were originally presented with the control panel in the VERTICAL position were then presented the HORIZONTAL position. This section of the experiment served to enable the Ss to determine which control position they prefer.

The major result of the study was that there was no "natural" or population stereotype found for EL adjustments in the VERTICAL position. A BACKWARD movement was found to be the response to both a VERTICAL and a DOWN command stimulus in the VERTICAL control position. Another result was that although the VERTICAL position was preferred by the Ss, the HORIZONTAL position is more conducive to better performance. Another result that supported past research indicated that lever controls should move in a direction that is consistent with the movement of a display.

It was found that for AZ adjustment the HORIZONTAL and VERTICAL positions are equally adequate as long as the axes and movements of the control and display are in the same direction.

It was recommended that EL control levers be placed in the HORIZONTAL position for missile operation adjustments. If one control lever is to be used for both AZ and EL adjustments, it is recommended that this should also be in the HORIZONTAL position.

REFERENCES

1. Andreas, B. G., Green, R. F., & Spragg, S. D. S. Transfer effects in following tracking resulting from reversal of the display-control relationship on alternate blocks of trials. J. Psychol., 1955, 40,421-430.

2. Andreas, B. G.,& Weiss, Bernard. Review of research on perceptual motor performance under varied display-control relationships. Rochester, N. Y.: Univer. Rochester 1954. (Contract A. F. 30 (602)-200, Sci. Rep. No. 2).

3. Bilodeau, E. A. Modifications of direction of movement preference with independent variation of two stimulus dimensions. Research Bulletin 51-12, Air Training Command, Human Resources Research Center, Lackland Air Force Base, San Antonio, Texas 1951.

4. Brown, J. S.,& Wieben, E. W. & Norris, E. B. Discrete movements toward and away from the body in the horizontal plane. SDC Project 20-M-1, Sept. 1948 (U) Report #57-2-6.

5. Carter, L. F.,and Murray, N. L. A study of the most effective relationships between selected control and indicator movements. In Fitts, P. M. (Ed.) Psychological Research on Equipment Design. U. S. Government Printing Office, 1947, 147-157.

6. Chapanis, A., Garner, W. R., and Morgan, C. T. Applied Experimental Psychology. New York: Wiley, 1949, Chap. 11.

7. Edwards, Allen. Experimental Design in Psychological Research. New York. Rinehart and Co., 1950, Chap. 12.

8. Fitts, P. M. (Ed.) Psychological Research on Equipment Design. U. S. Government Printing Office, 1947.

9. Goodwin, A., and Wallis, D. Some human factors in the design of controls. An evaluation of the literature, Naval Motion Study Unit, Department of Physical Research and the Senior Psychologist Report #61, 1954.

10. Green, R. F.,Andreas, B. G., Norris, E. B., and Spragg, S. D. S. The effects of continuity in display and control movement relationships on two-hand tracking performance. Special Devices Center Project 20-M-Id, Contract N6Onr - 241, T.O. 6.

11. Humphries, M., Performance as a function of control-display relations, positions of the operator and locations of the control. J. App. Psych., 1958, 42, 311-316.

12. Humphries, M.,& Shephard, A. H. Performance on several control-display arrangements as a function of age. Can. J. Psychol., 1955, 9, 231-238.

13. Lewis, D., & McAllister, Dorothy E. An investigation of individual susceptibility to interference. Office of Naval Res., Special Device Center, Port Washington, L. I., N. Y., 1950. (Tech. Rep. SDC 938-1-10).

14. Lewis, D., & Mc Allister, Dorothy E., & Adams, J. A. Facilitation and interference in performance on the modified Mashburn Apparatus: I. The effects of varying the amount of original learning. J. Exp. Psychol., 1951, 41, 247-260

15. Lewis, D., & Shephard, A. H. Devices for studying associative interference in psycho-motor performance: IV. The Turret Pursuit Apparatus. J. Psychol., 1950, 29, 173-182.

16. Lewis, D., & Shephard, A. H. Prior learning as a factor in shaping performance curves. Proc. Nat. Acad. Sci., 1951, 37, 124-131.

17. Lewis, D., & Smith, P. N. Retroactive facilitation and interference in performance on the modified two-hand coordinator. Office of Naval Research, Special Devices Center, Port Washington, L. I., N. Y., 1951 (Tech. Rep. SDC 166-00-2).

18. McAllister, Dorothy E. Retroactive facilitation and interference as a function of level of learning. Amer. J. Psychol., 1952, 65, 218-232.

19. McFarland, R. A., et al. Human Body Size and Capabilities in the Design and Operation of Vehicular Equipment. Harvard School of Public Health, Boston, Mass., 1953, 74-75.

20. Mitchell, M. J. H. Direction of movement of machine controls: III. A two-handed task in a discontinuous operation. Psychological Laboratory, Ministry of Supply, Cambridge, England, S. M. 10018 (S), 1947.

21. Mitchell, M. J. H. Direction of movement of machine controls: IV. Right or left-handed performance in a continuous task. Medical Research Council, Unit of Applied Psychology, Cambridge, England MRC 48/371, APU No. 85, 1948.

22. Mitchell, M. J. H. Direction of movement of machine controls: V. A two-handed performance in a continuous task. Applied Psychology Research Unit, Psychological Laboratory, Cambridge England, APU 110/49, 1949.

23. Norris, Eugenia B., & Spragg, S.D.S. Performance on a following tracking task (modified SAM two-hand coordinator test) as a function of the planes of operation of the controls. J. Psychol., 1953, 35, 107-117.

24. Shephard, A. H. The Toronto Complex Coordinator, Can. J. Psychol., 1955, 9, 7-14.

25. Vince, M. A. Direction of movement of machine controls. Ministry of Supply, Flying Personnel Research Committee, Psychological Laboratory, Cambridge, England, FPRC 637, 1945.

26. Vince, M. A. Learning and retention of an "unexpected" control-display relationship under stress conditions. Medical Research Council, Applied Psychology Unit, Psychological Laboratory, Cambridge, England, APU 125/50, 1950.

27. Vince, M. A., & Mitchell, M.J.H. Direction of movement of machine controls: (continued) Ministry of Supply. Psychological Laboratory, Cambridge, England, SM 2861 (S) 1946.

28. Warrick, M. J. Direction of movement in the use of control knobs to position visual indicators. In Fitts, P. M. (Ed.) Psychological Research on Equipment Design, U. S. Government Printing Office, 1947.

APPENDIX A. FREQUENCY DATA ON ELEVATION VARIABLE

STIMULUS COMMAND

UP

MOVEMENT RESPONSES	VERTICAL	HORIZONTAL	
AWAY	2	14	16
TOWARD	14	2	16
	16	16	32

STIMULUS COMMAND

DOWN

MOVEMENT RESPONSES	VERTICAL	HORIZONTAL	
AWAY	5	3	8
TOWARD	11	13	24
	16	16	32

APPENDIX B. FIRST RESPONSE LATENCY DATA FOR AZIMUTH VARIABLE

	HORIZONTAL COMMAND		VERTICAL COMMAND	
Subject	Right	Left	Right	Left
1	1.00	.25	.55	.58
2	1.00	.65	.70	.72
3	1.00	.98	.48	.50
4	.64	.62	.60	.95
5	.88	.20	.67	.50
6	.70	.87	.48	.85
7	.87	.78	.32	4.48
8	.90	.20	.68	1.10
9	1.02	2.00	.60	.97
10	.66	.58	.74	1.00
11	.42	.60	2.20	.82
12	.80	1.10	.75	.80
13	.90	1.10	1.42	.87
14	1.40	1.10	.35	1.20
15	.92	2.20	.98	.80
16	1.03	.85	1.50	.40
EX	14.14	14.08	13.02	16.54
EX^2	13.21	17.16	14.29	30.51

APPENDIX C. FIRST-RESPONSE LATENCY DATA FOR ELEVATION VARIABLE

Subject	HORIZONTAL COMMAND Up	HORIZONTAL COMMAND Down	VERTICAL COMMAND Up	VERTICAL COMMAND Down
1	.25	.50	.75	.52
2	.78	.85	.60	.52
3	.38	.35	.22	.60
4	.50	2.50	.97	.68
5	1.25	.54	2.00	.70
6	.40	.50	.47	1.10
7	.62	.80	1.10	.68
8	.80	.76	.52	.70
9	1.20	1.80	.97	1.40
10	1.00	.55	1.10	4.00
11	.34	.68	.74	.98
12	1.30	.43	1.28	1.00
13	1.20	.75	1.12	1.00
14	2.00	8.50	1.30	.80
15	.87	.97	.98	1.60
16	1.10	1.20	.35	1.50
EX	13.99	21.68	14.47	17.78
EX^2	15.46	88.49	15.98	30.39

DISTRIBUTION LIST

Director, Army Research Office
Office, Chief Research & Development
U.S. Army - The Pentagon, Wash
Washington 25, D. C.
Attn: Dr. Lynn E. Baker 1 copy

Chief of Ordnance
Department of the Army
Washington 25, D. C.
Attn: ORDTB 2 cy

Commanding General
Army Rocket & Guided Missile Agency
Redstone Arsenal, Alabama
Attn: ORDXR-RT (Mr. D. I. Graham) 1 cy
Technical Library 1 cy

Commanding General
Army Ballistic Missile Agency
Redstone Arsenal, Alabama
Attn: ORDAB-DSP (Mr. J. W. Carter) 1 cy

Commanding Officer
Springfield Armory
Springfield, Mass.
Attn: ORDBD-LWDB(PC) 1 cy

Commanding Officer
Watervliet Arsenal
Watervliet, New York
Attn: ORDBF-RE 1 cy

Commanding General
Quartermaster Research and
Development Center
Natick, Mass.
Attn: Environmentsl Protection
Research Div. 1 cy

Director, Walter Reed Army
Institute of Research
Walter Reed Army Medical Center
Washington, D. C.
Attn: Neuropsychiatry Div. 1 cy

Commanding General
U.S. Army Ordnance Tank-Automotive
Command
Center Line, Michigan
Attn: ORDMC-RE.2 1 cy

Commanding General
U.S. Army Ordnance Weapons Command
Rock Island, Illinois
Attn: ORDOW-TE 1 cy

Commanding General
Frankford Arsenal
Philadelphia 37, Pa.
Attn: ORDBA-LZ 1 cy

Commanding Officer
Picatinny Arsenal
Dover, N. J.
Attn: ORDBB-TR 1 cy

Commanding Officer
Rock Island Arsenal
Rock Island Illinois
Attn: ORDBC-9310-TS 1 cy

Commanding Officer
Watertown Arsenal
Watertown 72, Mass.
Attn: ORDBE-9251 1 cy

Commanding Officer
Office USA Ordnance Research
Box CM, Duke Station
Durham, North Carolina 1 cy

HQ, USA Medical R&D Command
Main Navy Building
Washington 25, D. C.
Attn: NP & PP Res. Br. 1 cy

Commanding Officer
USA Medical Research Laboratory
Fort Knox, Ky.
Attn: Psychology Div. 1 cy

Technical Information Library
Bldg 313, APG 1 cy

Office of Technical Services
Department of Commerce
Washington 25, D. C.
Attn: Acquisitions Section 2 cy

Commanding General
USA Ordnance Training Command
Aberdeen Proving Ground, Md.
Attn: Liaison Div. 1 cy

Commanding Officer
Directorate of Medical Research
Army Chemical Center, Md.
Attn: Psychology & Human Engineering Br. 1 cy

Joint Liaison Office,
Bldg. 305, APG 1 cy

U.S. Army Leadership
Human Research Unit
Fort Ord, Calif. 1 cy

U.S. Army Armor
Human Research Unit
Fort Knox, Kentucky 1 cy

U.S. Army Infantry
Human Research Unit
Fort Benning, Ga. 1 cy

Director of Research
Training Methods Div.
Human Resources Research Office
P. O. Box 3596
Washington 25, D.C. 1 cy

Director of Research
USA Air Defense
Human Research Unit
Fort Bliss, Texas 1 cy

Detachment Leader, Human Resources
Research Army Aviation Detachment
P.O. Box 428
Fort Rucker, Alabama 1 cy

Commanding Officer
USA Ordnance Test Activity
Yuma Test Station, Ariz. 1 cy

Commanding Officer
USA Ordnance Test Detachment
Ft. Churchill, Manitoba, Canada 1 cy

Commanding Officer
Office of Naval Research Br. Office
495 Summer St.
Boston, Mass.
Attn: Dir., Bibliographical Service Proj.
Inst. for Appl. Exper. Psychol.
North Hall, Tufts College
Medford 55, Mass. 1 cy

Commanding General
White Sands Missile Range
Las Cruces, New Mexico
Attn: Technical Library 1 cy

Commanding General
U.S. Army Artillery Board
Fort Sill, Oklahoma 1 cy

Commanding General
U.S. Army Armor Board
Fort Knox, Kentucky 1 cy

Commanding General
U.S. Army Infantry Board
Fort Benning, Ga. 1 cy

Commanding General
U.S. Army Air Defense Board
Fort Bliss, Texas 1 cy

U.S. Navy Electronics Laboratory
San Diego 52, California
Attn: Ch, Human Factors Div. 1 cy

Canadian Army Staff (Washington)
2450 Massachusetts Ave. N.W.
Washington 8, D. C. 1 cy

Operations Research Office
7100 Connecticut Ave.
Chevy Chase, Maryland 1 cy

American Institute for Research
410 Amberson Avenue
Pittsburgh 32, Pa.
Attn: Dr. R. B. Miller 1 cy

The Franklin Institute
20th St & Ben Franklin Parkway
Philadelphia 3, Pa.
Attn: Electrical Eng. Library 1 cy

Commander
Armed Services Technical
Information Agency
Arlington Hall Station
Arlington 12, Va.
Attn: TIPDR 10 cy

Commanding Officer
Naval Research Laboratory
4th & Chesapeake St., S. W.
Washington 25, D. C.
Attn: Code 5120 Eng. Psychology 1 cy
Code 5143A Systems Analysis 1 cy

Hughes Aircraft Co.
Florence Ave. at Teal St.
Culver City, Calif.
Attn: Engineering Library 1 cy

Director
Jet Propulsion Laboratory
Pasadena 2, California 1 cy

Commanding Officer
Diamond Ordnance Fuze Laboratories
Washington 25, D. C.
Attn: Tech. Reference Sec. 1 cy
Mr. H. C. Brown 1 cy

AD ______ Accession No. ______

USA Ord Human Engineering Laboratory
Aberdeen Proving Ground, Maryland
INVESTIGATION OF NATURAL MOVEMENTS IN AZIMUTH AND ELEVATION LEVER CONTROL ADJUSTMENTS FOR HORIZONTAL AND VERTICAL POSITIONS.
Richard G. Lazar & James R. Williams. Tech Memo #3-59 ORD Proj TBI-1000 Unclassified.

This study was designed to: (1) Determine population stereotypes or "natural" movements involved in the operation of levers designed to control Elevation and Azimuth Movements. (2) Determine in which plane levers should be placed to better effect control; i.e., the HORIZONTAL or the VERTICAL plane.

One hundred twenty-eight United States Army enlisted personnel were tested on two types of control panels, one VERTICAL and one HORIZONTAL with an Azimuth and Elevation control on each control panel.

The results indicated that there is a consistent relationship between RIGHT and LEFT control movements and RIGHT and LEFT movements of a display in both the HORIZONTAL and VERTICAL positions. However, the major finding was that there is no such consistency or "natural" movement or population stereotype with vertically positioned lever controls which move FORWARD and BACKWARD when these controls are associated with an UP and DOWN display movement.

UNCL

1. Lever Control Adjustments.
2. Control Movements.
3. Elevation and Azimuth Movements - Levers.
4. ORD Proj TBI-1000

AD ______ Accession No. ______

USA Ord Human Engineering Laboratory
Aberdeen Proving Ground, Maryland
INVESTIGATION OF NATURAL MOVEMENTS IN AZIMUTH AND ELEVATION LEVER CONTROL ADJUSTMENTS FOR HORIZONTAL AND VERTICAL POSITIONS.
Richard G. Lazar & James R. Williams. Tech Memo #3-59 ORD Proj TBI-1000 Unclassified.

This study was designed to: (1) Determine population stereotypes or "natural" movements involved in the operation of levers designed to control Elevation and Azimuth Movements. (2) Determine in which plane levers should be placed to better effect control; i.e., the HORIZONTAL or the VERTICAL plane.

One hundred twenty-eight United States Army enlisted personnel were tested on two types of control panels, one VERTICAL and one HORIZONTAL with an Azimuth and Elevation control on each control panel.

The results indicated that there is a consistent relationship between RIGHT and LEFT control movements and RIGHT and LEFT movements of a display in both the HORIZONTAL and VERTICAL positions. However, the major finding was that there is no such consistency or "natural" movement or population stereotype with vertically positioned lever controls which move FORWARD and BACKWARD when these controls are associated with an UP and DOWN display movement.

UNCL

1. Lever Control Adjustments.
2. Control Movements.
3. Elevation and Azimuth Movements - Levers.
4. ORD Proj TBI-1000